Validation of OFDM model in ns-3

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Abstract

This technical note publishes a new frame error rate model for OFDM signals for use in the ns-3 discrete event network simulator wireless models. The new error rate model is more closely aligned with recently published experimental results from a physical-layer testbed.

I. INTRODUCTION

The 802.11g extension to the IEEE Wireless LAN standard for 2.4 GHz [1] specifies a physical layer based on orthogonal frequency division multiplexing (OFDM). The ns-3 network simulator is a packet-based, discrete-event network simulator with a set of wireless LAN models in addition to other models related to networking. To first order, when simulating the reception of a frame, the ns-3 physical layer model calculates the assumed signal to noise ratio based on parameters in the system being modelled and consults a look-up table based on the mode of operation to determine the probability of a successful frame reception. The look-up table is based on previously published results incorporated into the YANS simulator [2], originally modelling IEEE 802.11a at 5 GHz. Simulated frame receptions are independent and identically distributed events according to a uniform random variate generated for each frame and compared against the probability value.

A recent result [3] shows significant differences between the ns-3 model and measurements from a clear channel wireless emulation test bed [4]. This motivated the present study of the OFDM frame error rate model of ns-3 described in [2]. As a result, we found a different detailed error rate model for OFDM presented in [5]. This model was derived based on the OFDM waveform definition (see section 2 and appendix A in [5]).

II. MODEL DERIVATION

The results from section 3 in [5] are now summarized and applied to ns-3. Let P_R be the total received power and P_{R_c} be the received power on one of the OFDM carriers. Equation 3.1.3 in [5] can be extended as follows:

$$SNR = \frac{P_R}{52\Delta_F N_0} = \frac{(1/52)P_R}{N_0\Delta_F} = \frac{P_{R_c}}{N_0\Delta_F} = \frac{P_{R_c}}{\sigma_{ni}^2} \tag{1}$$

Since 802.11a/g use hard-decision of punctured codes, the coded BER is calculated with the following Chernoff bound:

$$P_e < \frac{1}{2b}\sum_{d=d_{min}}^{\infty}\beta_d D^d, \text{ where } D = \sqrt{4p(1-p)} \tag{2}$$

Table I provides the list of values for the variables in equation (2) used in the revised ns-3 implementation. F and $Q(x)$ in Table I are defined as follows:

$$F = \frac{4}{5}\cdot\frac{48}{52} \tag{3}$$

and

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^\infty e^{-(\frac{t^2}{2})}dt = \frac{1}{2}erfc(\frac{x}{\sqrt{2}}) \tag{4}$$

Data Rate	**Modulation**	**Coding Rate**	**BpS**	**Uncoded Error Rate p**	β_d	b	**References**
6 Mbps	BPSK	$\frac{1}{2}$	48	$Q(\sqrt{2SNR}) = Q(\sqrt{2 \cdot F \cdot \frac{E_b}{N_0}})$	Table 3.1.1	1	Equations 3.1.1, 3.1.14
9 Mbps	BPSK	$\frac{3}{4}$	48	$Q(\sqrt{2SNR}) = Q(\sqrt{2 \cdot F \cdot \frac{E_b}{N_0}})$	Table 3.1.2 ($r = \frac{3}{4}$)	3	Equations 3.1.1, 3.1.14
12 Mbps	QPSK	$\frac{1}{2}$	96	$Q(\sqrt{SNR}) = Q(\sqrt{2 \cdot F \cdot \frac{E_b}{N_0}})$	Table 3.1.1	1	Equations 3.1.5, 3.1.14
18 Mbps	QPSK	$\frac{3}{4}$	96	$Q(\sqrt{SNR}) = Q(\sqrt{2 \cdot F \cdot \frac{E_b}{N_0}})$	Table 3.1.2 ($r = \frac{3}{4}$)	3	Equations 3.1.5, 3.1.14
24 Mbps	16-QAM	$\frac{1}{2}$	192	$\frac{3}{4}Q(\sqrt{\frac{SNR}{5}}) = \frac{3}{4}Q(\sqrt{F \cdot \frac{4}{5} \cdot \frac{E_b}{N_0}})$	Table 3.1.1	1	Equations 3.1.7, 3.1.15
36 Mbps	16-QAM	$\frac{3}{4}$	192	$\frac{3}{4}Q(\sqrt{\frac{SNR}{5}}) = \frac{3}{4}Q(\sqrt{F \cdot \frac{4}{5} \cdot \frac{E_b}{N_0}})$	Table 3.1.2 ($r = \frac{3}{4}$)	3	Equations 3.1.7, 3.1.15
48 Mbps	64-QAM	$\frac{2}{3}$	288	$\frac{7}{12}Q(\sqrt{\frac{SNR}{21}}) = \frac{7}{12}Q(\sqrt{F \cdot \frac{6}{21} \cdot \frac{E_b}{N_0}})$	Table 3.1.2 ($r = \frac{2}{3}$)	2	Equations 3.1.10, 3.1.15
54 Mbps	64-QAM	$\frac{3}{4}$	288	$\frac{7}{12}Q(\sqrt{\frac{SNR}{21}}) = \frac{7}{12}Q(\sqrt{F \cdot \frac{6}{21} \cdot \frac{E_b}{N_0}})$	Table 3.1.2 ($r = \frac{3}{4}$)	3	Equations 3.1.10, 3.1.15

TABLE I

SUMMARY OF BER MODEL IN [5]

III. RESULTS

Figure 8 in [3] compares the results from ns-3, from a physical layer testbed, and from a new physical layer emulator. The testbed used was the wireless emulator from Carnegie Mellon University, in which real 802.11g devices (based on Atheros AR5212 chipsets) and patched versions of the madwifi-0.9.4 drivers were interconnected by a digital FPGA-based channel emulator. While the slopes of the curves are similar, the results from ns-3 are roughly 8-10 dB better than experimentally obtained. The difference is hypothesized in [3] to be due to a suboptimal implementation of the estimator in that chipset.

Figure 1 shows the frame error rate verse SNR using the existing ns-3 `YansErrorRateModel` class, while Figure 2 shows the corresponding results using the new `NistErrorRateModel` developed in Section II. It is clear that the data in Figure 2 is much closer to the experimental data reported in Figure 8 of [3]; in particular, the new model is generally within 1 dB of the experimental results. Therefore, we would like to recommend `NistErrorRateModel` as the default OFDM frame error rate model for ns-3, at least for clear channel (non-interference) cases.

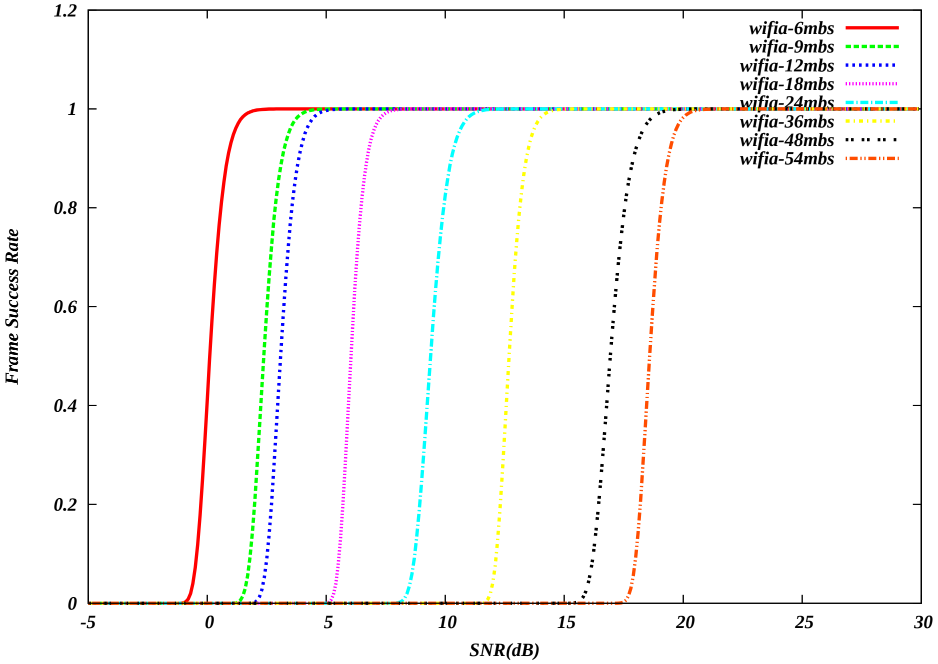

Fig. 1. Frame Error Rate of Yans Model

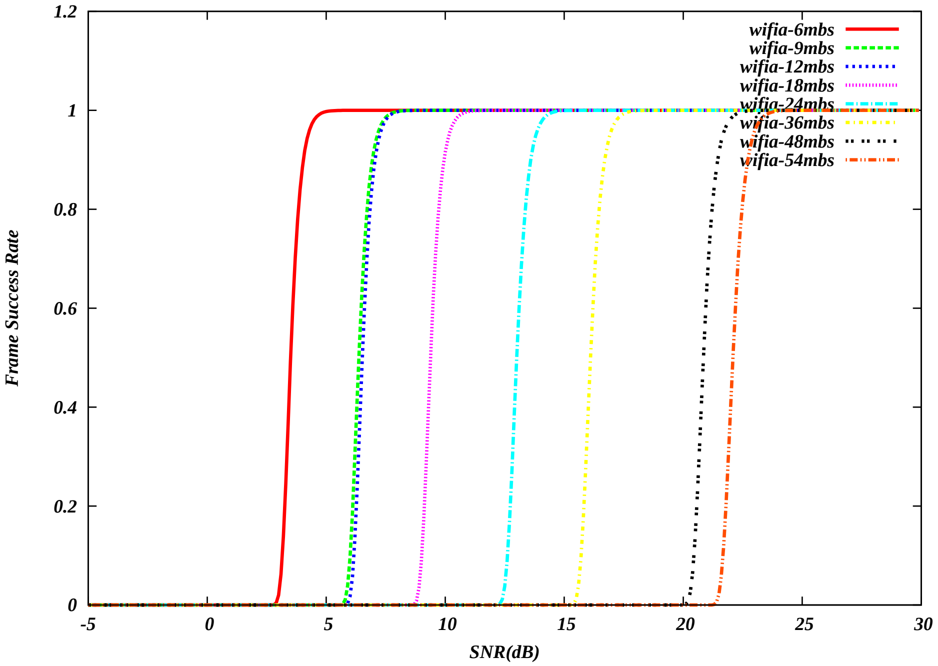

Fig. 2. Frame Error Rate of NIST Model

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